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(54) Data compression

(57) Data compression apparatus in which input data is compressed according to a target output data quantity using a stage of data quantisation, the apparatus comprises: one or more trial quantisers for selecting a degree of quantisation so that the target output data quantity is not exceeded; a data selector for selecting a subset of the current data to be quantised; a data store for storing the subset of data; a backsearch quantiser and dequantiser for sequentially quantising and dequantising the subset of data at a plurality of degrees of quantisation including the degree of quantisation selected by the trial quantiser(s) and one or more harsher degrees of quantisation; a comparator for comparing data quantised and dequantised by the backsearch quantiser with the stored subset of data, to detect errors introduced by the quantisation and dequantisation by the backsearch quantiser; and a quantisation selector for selecting a final degree of quantisation for use in compression of the current data, the final degree of quantisation being that degree detected by the comparator to introduce the fewest errors during quantisation and dequantisation of the subset of data by the backsearch quantiser.

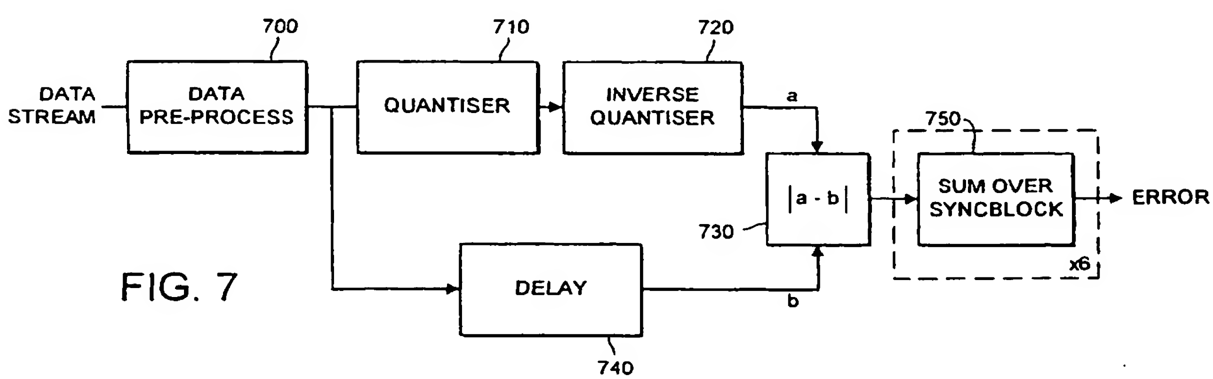

FIG. 7

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Description

[0001] This invention relates to data compression.

[0002] Some data compression systems, such as image data compression systems, use trial compressions to try to arrive at the most appropriate quantisation factor to achieve a desired output bit rate.

[0003] In one previously proposed system, trial quantisations are carried out at, say, ten possible quantisation values spread across the available range of quantisation values. The two trial quantisation values which provide an output bit rate falling either side of the desired value are identified, and a more detailed trial carried out in the reduced range between those two values. This can identify the quantisation value corresponding to the least harsh quantisation of the data which still complies with the target bit rate of the system.

[0004] However, it has been established that for some classes of data - for example, image data and/or data which has previously been compressed and decompressed - this arrangement does not necessarily provide the *best* quantisation value. A process sometimes referred to as "backsearch" has been devised to alleviate this problem.

[0005] The backsearch process starts with the quantisation value identified by the trial quantisations referred to above, and then tests that value and a number of adjacent values providing successively harsher degrees of quantisation. The test used is to apply quantisation followed immediately by dequantisation to the input data using each of the values under test and, in each case, to compare the resultant data with a delayed (i.e. not quantised) version of the input data. The quantisation value (of those tested) giving the fewest errors is then selected for the final, output stage of quantisation.

[0006] However, like many aspects of data compression, this additional test requires a large amount of fast processing circuitry in order to apply test quantisations and dequantisations to the input data at several quantisation values in parallel. This is a particular problem when the compression circuitry is to be implemented as an integrated circuit such as an ASIC (application specific integrated circuit).

[0007] This invention provides data compression apparatus in which input data is compressed according to a target output data quantity using a stage of data quantisation, the apparatus comprising:

one or more trial quantisers for selecting a degree of quantisation so that the target output data quantity is not exceeded;

a data selector for selecting a subset of the current data to be quantised;

a data store for storing the subset of data;

a backsearch quantiser and dequantiser for sequentially quantising and dequantising the subset of data at a plurality of degrees of quantisation including the degree of quantisation selected by the trial quantiser(s) and one or more harsher degrees of quantisation;

a comparator for comparing data quantised and dequantised by the backsearch quantiser with the stored subset of data, to detect errors introduced by the quantisation and dequantisation by the backsearch quantiser; and

a quantisation selector for selecting a final degree of quantisation for use in compression of the current data, the final degree of quantisation being that degree detected by the comparator to introduce the fewest errors during quantisation and dequantisation of the subset of data by the backsearch quantiser.

[0008] The invention recognises that the backsearch process can be performed and a useful result achieved using only a subset of the data to be quantised. This can dramatically reduce the amount of hardware needed to implement this function.

[0009] In a preferred embodiment, instead of being performed in parallel, the backsearch process can be performed in a time-division-multiplexed fashion using just a single set of quantiser and dequantiser.

[0010] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, throughout which like references refer to like parts, and in which:

Figure 1 is a schematic diagram of a bit-rate reducing encoder and a corresponding decoder for use with a magnetic tape channel;

Figures 2 to 4 schematically illustrate the bit-rate reducing encoder of Figure 1;

Figure 5 schematically illustrates an element of a previously proposed backsearch unit;

Figure 6 is a schematic diagram of a previously proposed backsearch unit;

Figure 7 is a schematic diagram of a backsearch unit according to an embodiment of the invention; and

Figure 8 is a schematic diagram of a data stream generated by the data pre-processor.

[0011] Figure 1 is a schematic diagram of a tape recording and reproducing system comprising a bit-rate reducing encoder 10, a tape channel 20, tape recording and reproducing apparatus 30 and a corresponding data decoder 40.

[0012] The encoder 10 receives an input high definition video signal and encodes it to form a bit-rate reduced (BRR) signal for recording on the tape medium. Similarly, the decoder 40 receives a BRR signal reproduced from the tape medium and decodes it to form an output high definition video signal.

[0013] A stage of error correction coding for recording, and corresponding decoding for replay (not shown) may be employed.

[0014] Referring now to Figure 2, the input video signal and a video clock are supplied to a field/frame adaption circuit 100, a phase lock loop 110, a video shuffler 120 and a system controller 130.

[0015] The field/frame adaption circuit 100 is used to control switching of the encoder between a frame-based mode of operation and a field-based mode of operation. This switching occurs at a scene change, so that a field-based mode of operation is used for the frame of a scene change.

[0016] In order to detect a scene change in the input video signal, the field/frame adaption circuit 100 divides each input field into 16 blocks, each being 300 pixels by 135 lines. The dc level and variance of each block for each field are then calculated as follows:

$dc = \Sigma$ (pixel value)

$variance = \Sigma$ (pixel value)^2

[0017] The variance of the blocks is then normalised as follows:

$$\text{normalised variance} = \Sigma\,(\text{pixel value})^2 / \Sigma\,(\text{pixel value})$$

[0018] The dc level and variance for each block of the two fields comprising a single frame are then compared (on a block-by-corresponding-block basis) to detect whether the two fields are considered to be similar. The following relationships are used to make this detection:

(a) if $dc_{fld1} \times dc_{lower\ threshold} > dc_{fld0}$
and $dc_{fld1} \times dc_{upper}$ threshold $< dc_{fld0}$
then dc_{fld1} is considered to be **similar** to dc_{fld0}

(b) if $var_{fld1} \times var_{lower\ threshold} > var_{fld0}$
and $var_{fld1} \times var_{upper}$ threshold $< var_{fld0}$
then var_{fld1} is considered to be **similar** to var_{fld0}

[0019] The number of dc and variance blocks that are similar between the two fields are then compared to separate thresholds:

if $number\_similar_{dc\ blocks} >$ dc block threshold
and $number\_similar_{var\ blocks} >$ var block threshold

then the two fields are considered to be part of the same video scene.

[0020] The result of this detection is supplied on a control output 102 from the field/frame adaption circuit 100.

[0021] The PLL 110 receives the 46.4 MHz clock supplied to the encoder and derives other clock signals required by the encoder apparatus from that clock signal.

[0022] The system controller 130 controls the apparatus to operate in the manner described.

[0023] The video shuffler 120 receives pixels of the input video signal and stores them temporarily in an external shuffle RAM 140. It then reads blocks of pixels from the external shuffle RAM according to a predetermined shuffle pattern so that blocks of pixels which are adjacent in the image are not read out at adjacent positions in the shuffle pattern.

[0024] The reason for this measure is to try to alleviate the effect of data losses (e.g. due to a tape drop-out or similar) on the picture reconstructed by the decoder apparatus. Because pixel blocks which are adjacent in the image are separated from one another in the resulting bit stream (because they are shuffled by the video shuffler 120), a short duration data loss might affect a number of pixel blocks but not their immediate neighbours in the image. This allows data concealment to be used to reconstruct the missing blocks.

[0025] The current frame is written to the external RAM while the previous frame is read, in a shuffled manner, from the external RAM.

[0026] The shuffled data from the video shuffler 120 is supplied to a discrete cosine transform (DCT unit 150), an activity calculator 160 and (referring to Figure 3) a bit allocator 170.

[0027] The DCT unit 150 transform each pixel block supplied from the video shuffler 120 into a corresponding block of DCT coefficients using known techniques. These coefficients are supplied to the bit allocator 170.

[0028] The activity calculator 160 generates so-called "activity codes" and corresponding offsets to be applied to the quantisation index for each block of data. These codes specify the so-called activity of each block, assessed according to the following principles:

(i) a block containing more detail (measured for example by the variance of the pixel values within the block) has a higher activity than a block having less detail;

(ii) a block predominantly containing colours associated with skin tones is quantised less harshly (i.e. given a lower notional activity) than a block predominantly not containing such colours;

(iii) a block having a very low or a very high average luminance level is quantised more harshly (i.e. given a higher notional activity) than a block having a mid-range average luminance level (Weber's law). For example, if a block's average luminance level is above 224 or below 32 (in an eight bit system) then a constant value is added to the calculation of the block's activity. If the block's average luminance level is between 32 and 224 then the activity calculation is unaltered.

[0029] In general, the activity codes are used to control the later operation of the encoder, so that pixel blocks having a higher activity are subjected to harsher compression, since it is less likely that the viewer would spot compression artifacts in that block when the block is subsequently decompressed. Blocks having a low activity, e.g. relatively "smooth" surfaces, relatively dark areas or areas having colours corresponding to skin tones, are compressed less harshly, since the user is

more likely to spot compression artifacts in those areas.

[0030] The quantisation index offsets are embedded in the bitstream, whereas the activity codes (which are needed to specify the quantisation offsets to be used on decoding) are supplied separately for possible "optimisation" - see below.

[0031] The bit allocator 170 receives DCT data from the DCT encoder 150 and activity data from the activity calculator 160. The bit allocator 170 performs a trial quantization of the DCT data, followed by a trial part of an entropy encoding process.

[0032] Using these techniques, the bit allocator calculates the number of bits which would be required to encode each DCT block at one of ten quantization "base" values: 7, 13, 19, 25, 31, 37, 43, 49, 55 and 61, subject to each block's quantisation index offset calculated by the activity calculator. Ultimately, the quantization level for each block is selected to a resolution of 1 (using the scale given above), but for the purposes of the bit allocator 170, the quantization base value is assessed to the nearest 6 on that scale.

[0033] At the output of the bit allocator, therefore, a figure derived from the nearest appropriate quantization base level from the selection given above is passed, together with a delayed version of the video data, to a further DCT unit 180, a binary search unit 190 and a backsearch unit 200. This process will be described further below, but in brief, a value 2 greater than the quantisation value giving just over the required bit rate is passed by the bit allocator.

[0034] The further DCT unit 180 again calculates DCT coefficients, this time based on the delayed version of the video data.

[0035] The binary search unit 190 carries out trial quantizations at quantization levels just above or just below the base quantization level, again modified by the quantisation index offsets associated with each block, to select one value within a range of -3 to +4 with respect to the base quantization level from the bit allocator.

[0036] A further trial quantization is carried out by the backsearch unit which tests the quantization level selected by the binary search unit 190, and assesses whether a higher quantization level could be used whilst still obtaining the same or fewer quantisation errors.

[0037] Finally, the selected quantization level, and the DCT blocks from the further DCT encoder 180, are supplied to a quantizer 210 where they are quantized according to the selected quantization level. The quantized data are passed to an entropy encoder 220 which generates variable length output data according to the standard principles of entropy encoding, so that more commonly occurring data patterns in the quantized data are encoded using shorter code words.

[0038] The data generated by the entropy encoder is then packed into "code blocks" for recording on tape by a data packer 230. The code blocks include header data, entropy-encoded data from a number of DCT blocks, activity codes associated with those blocks and an indication of the quantisation level used in forming the blocks. Error correcting codes are then applied to provide error correction when the code blocks are replayed from the tape. A code block comprises five "sync blocks", where a sync block is the smallest separately recoverable data item recorded on the tape in this system.

[0039] Figure 5 schematically illustrates an element of a previously proposed backsearch unit. Backsearch is a process for testing the quantization index value chosen by the binary search. As described above, binary search generates the *lowest* quantization index which produces fewer bits than the bit rate target. Backsearch then tests the six adjacent higher quantization indices to detect which is the *best* value to be used from those six choices.

[0040] In Figure 5, an element of the backsearch unit comprises a test quantizer 600, an inverse quantizer 610 using the same quantization index as the quantizer 600, a subtracter 620 and a delay element 630. So, the DCT data is subjected to a quantization and complementary inverse quantization process, then to be subtracted from a delayed version of the original DCT data. Carried out on the whole data stream, this comparison produces an error signal at the output of the subtracter 620.

[0041] Referring to Figure 6, a full backsearch unit comprises six elements 640 of the type shown in Figure 5. Each of these elements 640 operates with a different quantization index, namely:

QI(out)
QI(out) + 1
...
QI(out) + 5.

[0042] The error signals produced by each of the elements 640, representing the differences between the quantized and inverse-quantized DCT data and the original DCT data, are summed over a sync block and compared by a sum and compare unit 650. The sum and compare unit 650 selects that one of the possible quantization indices tested by the six elements 640 to be used in the final quantization stage for encoding the DCT data: QI(final) - the quantisation index giving the lowest error rate summed over the sync block.

[0043] Figure 7 is a schematic diagram of a backsearch unit according to an embodiment of the invention.

[0044] The backsearch unit of Figure 7 comprises a data pre-processor 700, followed by a quantiser 710, inverse quantiser 720, subtractor 730 and delay 740 similar to those shown in Figure 6. The output of the subtractor 730 is connected to a sum and compare unit 750.

[0045] In contrast to the previously proposed backsearch unit described earlier, Figure 7 illustrates the whole of the backsearch unit, that is, the parts 710, 720, 730 and 740 are not repeated six times as in Figure 6. The way in which this repetition of parts is avoided stems from the use and operation of the data pre-processor

700, and will be described below.

[0046] The data pre-processor 700 selects and stores a subset of the data stream supplied to the backsearch unit. It then supplies the subset of the data stream repeatedly to the quantiser 710 in a time-division-multiplexed manner. At each repetition, the quantiser 710 quantises the subset with a different quantisation factor, cycling through the range QI(out) ... QI(out) + 5.

[0047] So, as a first data subset is processed, e.g. at a quantisation factor QI(out), the resulting error amount from the subtractor 730 is stored by the sum and compare unit 750. As the next subset is processed, at a quantisation factor QI(out)+1, the resulting error amount is also stored. This process repeats, so that the sum and compare unit 750 builds up six cumulative stored error values over the course of processing a sync block, one value for each of the six possible quantisation factors QI (out)...QI(out) +5. At the end of processing a sync block, the quantisation factor of the six possible values which gives the lowest cumulative error value is selected for the eventual quantisation of that sync block.

[0048] Figure 8 is a schematic diagram of a data stream generated by the data pre-processor.

[0049] Each sync block is formed of a number of successive 64 byte DCT blocks 800, with one byte of control information 810. The data pre-processor 700 selects and stores a 10 byte subset 820 of the DCT block 800, and outputs that subset six times. By arranging that the subset 820 is no more than one sixth of the length of the original DCT block, the six repetitions of the subset 820 can be made in the time normally allocated to transmission of the original DCT block 800. So, the six trial quantisations and dequantisations required for the backsearch process can be performed successively, rather than in parallel, by using a single set of apparatus 710, 720, 730, 740 rather than six such sets in parallel.

[0050] As shown in the lower part of Figure 8, five bytes of padding data are added after the six repetitions of the subset 810, to make up the same quantity of data as the original DCT block 800.

[0051] The subset 810 selected by the data pre-processor can be, for example, 10 DCT coefficients selected from predetermined positions within the data stream (e.g. the first 10 coefficients), 10 non-zero coefficients (e.g. the first 10 non-zero coefficients or the 10 largest coefficients), or another predetermined or pseudorandomly selected pattern.

Claims

1. Data compression apparatus in which input data is compressed according to a target output data quantity using a stage of data quantisation, the apparatus comprising:

   one or more trial quantisers for selecting a degree of quantisation so that the target output data quantity is not exceeded;
   a data selector for selecting a subset of the current data to be quantised;
   a data store for storing the subset of data;
   a backsearch quantiser and dequantiser for sequentially quantising and dequantising the subset of data at a plurality of degrees of quantisation including the degree of quantisation selected by the trial quantiser(s) and one or more harsher degrees of quantisation;
   a comparator for comparing data quantised and dequantised by the backsearch quantiser with the stored subset of data, to detect errors introduced by the quantisation and dequantisation by the backsearch quantiser; and
   a quantisation selector for selecting a final degree of quantisation for use in compression of the current data, the final degree of quantisation being that degree detected by the comparator to introduce the fewest errors during quantisation and dequantisation of the subset of data by the backsearch quantiser.

2. Apparatus according to claim 1, in which:

   data to be quantised is received sequentially by the data selector in data blocks;
   the data selector is operable to select a subset of each block of data;
   the data selector and/or data store is operable to supply the subset to the backsearch quantiser and dequantiser repeatedly, with one repetition for each of the plurality of degrees of quantisation.

3. Apparatus according to claim 2, in which the subset is less than or equal to the block size divided by number of repetitions.

4. Apparatus according to any one of the preceding claims, in which the data to be quantised are data representing one or more images.

5. Apparatus according to any one of the preceding claims, in which the data to be quantised are frequency separated data.

6. Apparatus according to claim 5, in which the data to be quantised are DCT data.

7. Apparatus according to claim 6, in which the subset of data comprises a predetermined number of lowest spatial frequency coefficients of the DCT data.

8. Apparatus according to claim 6, in which the subset of data comprises a predetermined number of non-zero lowest spatial frequency coefficients of the DCT data.

9. Apparatus according to claim 6, in which the subset of data comprises a predetermined number of numerically largest spatial frequency coefficients of the DCT data.

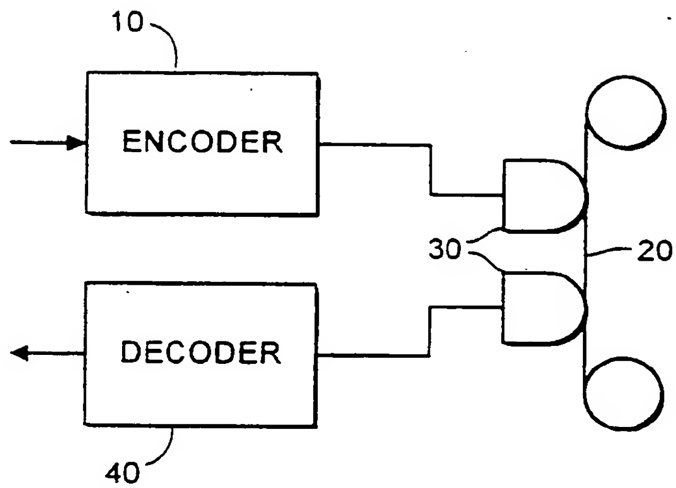

FIG. 1

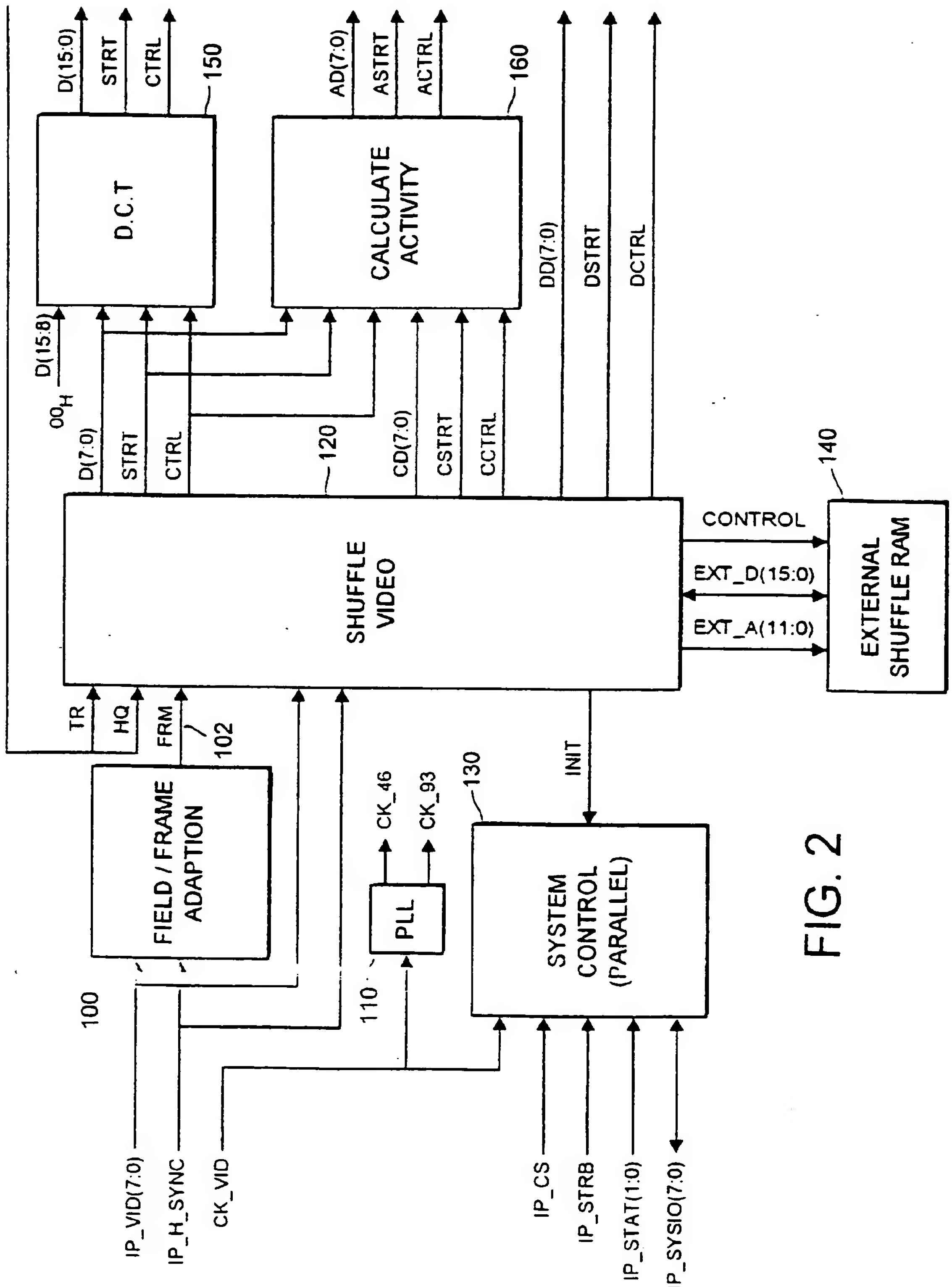
D(15:0)
STRT
CTRL
150
D.C.T
AD(7:0)
ASTRT
ACTRL
160
CALCULATE ACTIVITY
DD(7:0)
DSTRT
DCTRL
D(15:8)
00H
D(7:0)
STRT
CTRL
120
CD(7:0)
CSTRT
CCTRL
140
SHUFFLE VIDEO
CONTROL
EXT_D(15:0)
EXT_A(11:0)
EXTERNAL SHUFFLE RAM
TR
HQ
FRM
102
FIELD / FRAME ADAPTION
CK_46
CK_93
PLL
110
130
INIT
SYSTEM CONTROL (PARALLEL)
100
IP_VID(7:0)
IP_H_SYNC
CK_VID
IP_CS
IP_STRB
IP_STAT(1:0)
IP_SYSIO(7:0)

FIG. 2

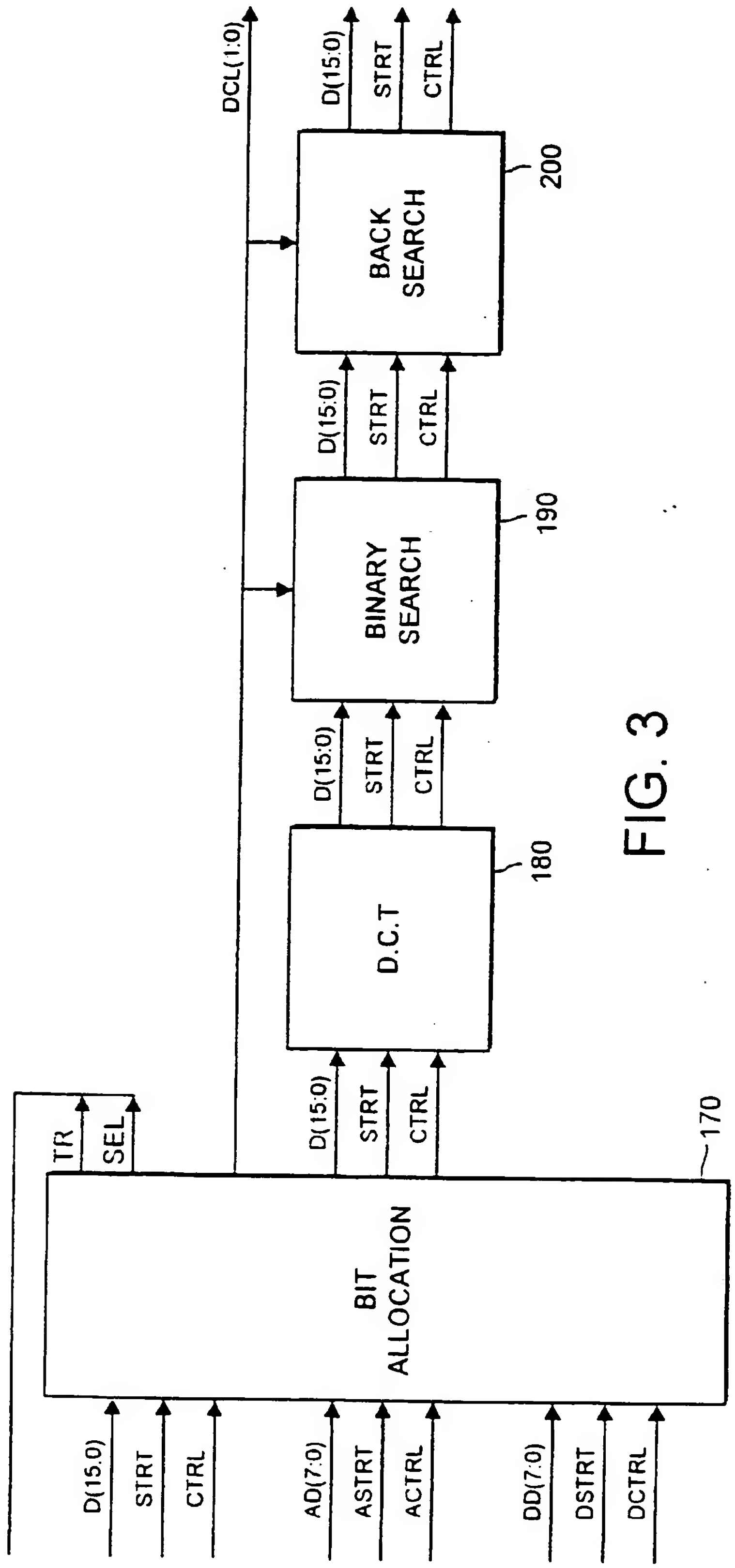
DCL(1:0)
D(15:0)
STRT
CTRL
BACK SEARCH
200
BINARY SEARCH
190
D.C.T
180
TR
SEL
BIT ALLOCATION
170
AD(7:0)
ASTRT
ACTRL
DD(7:0)
DSTRT
DCTRL

FIG. 3

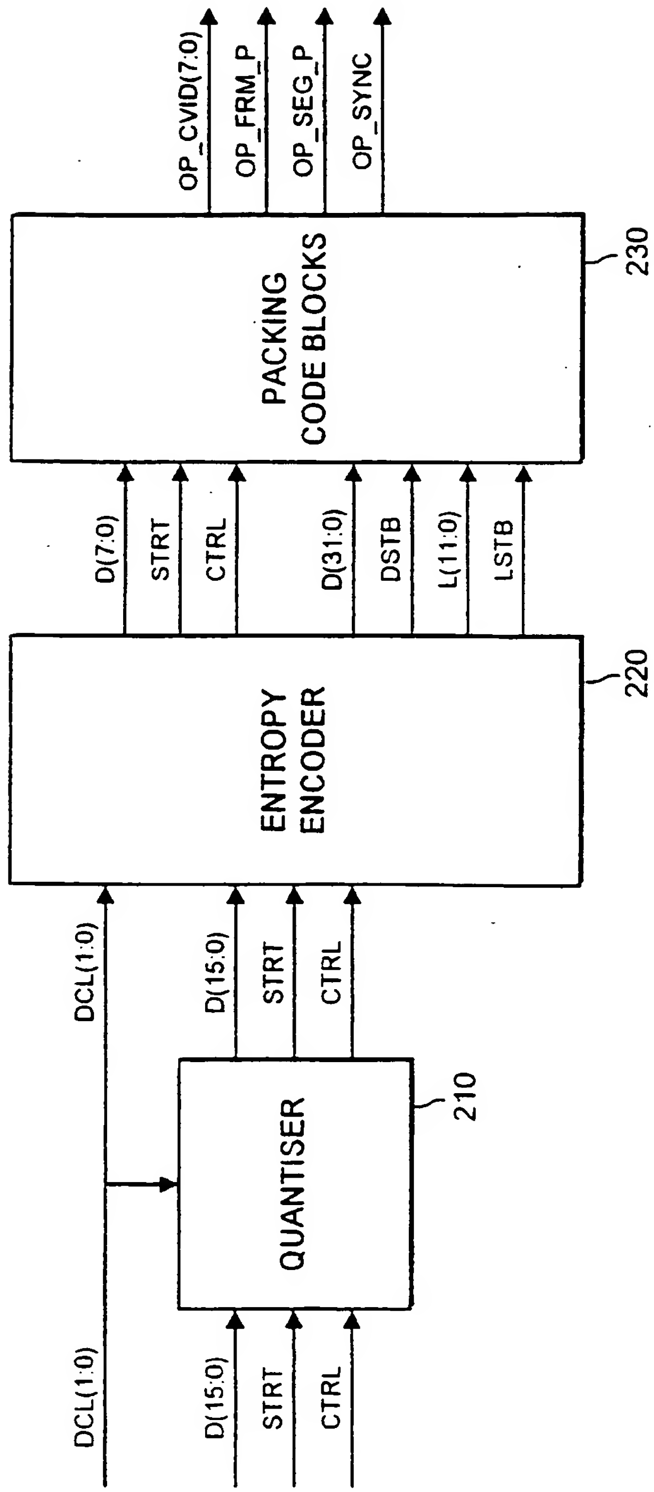
DCL(1:0)
D(15:0)
STRT
CTRL
QUANTISER
210
DCL(1:0)
D(15:0)
STRT
CTRL
ENTROPY ENCODER
220
D(7:0)
STRT
CTRL
D(31:0)
DSTB
L(11:0)
LSTB
PACKING CODE BLOCKS
230
OP_CVID(7:0)
OP_FRM_P
OP_SEG_P
OP_SYNC

FIG. 4

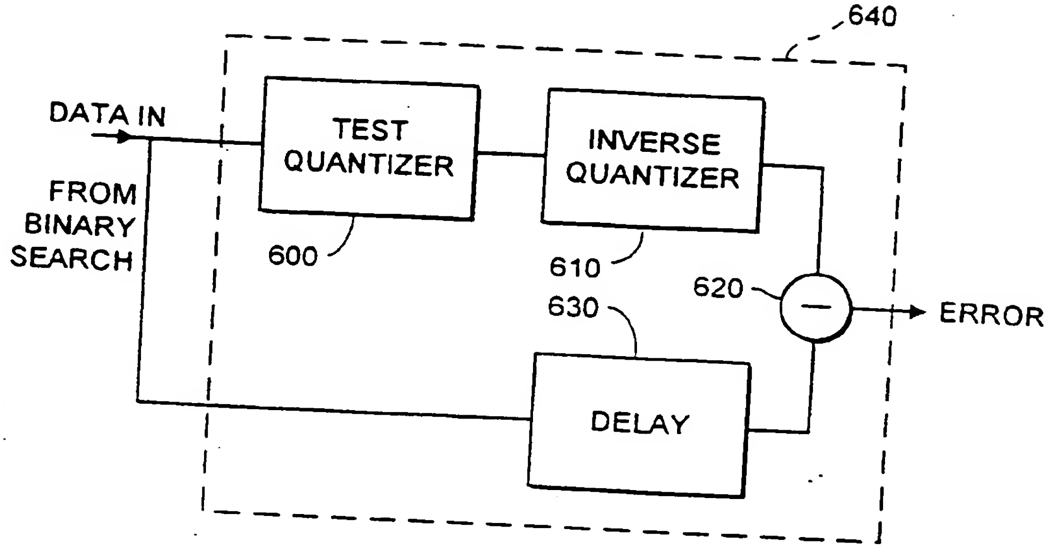
640
DATA IN
FROM
BINARY
SEARCH
TEST
QUANTIZER
600
INVERSE
QUANTIZER
610
620
630
ERROR
DELAY

FIG. 5

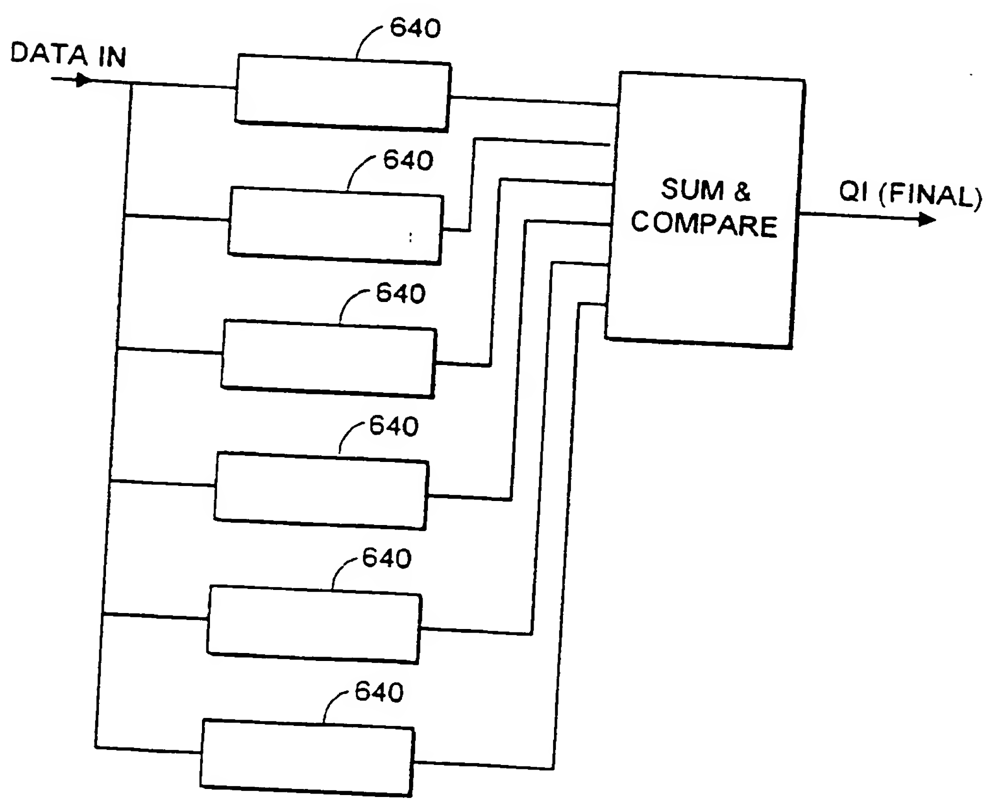
DATA IN
640
640
640
640
640
640
SUM &
COMPARE
QI (FINAL)

FIG. 6

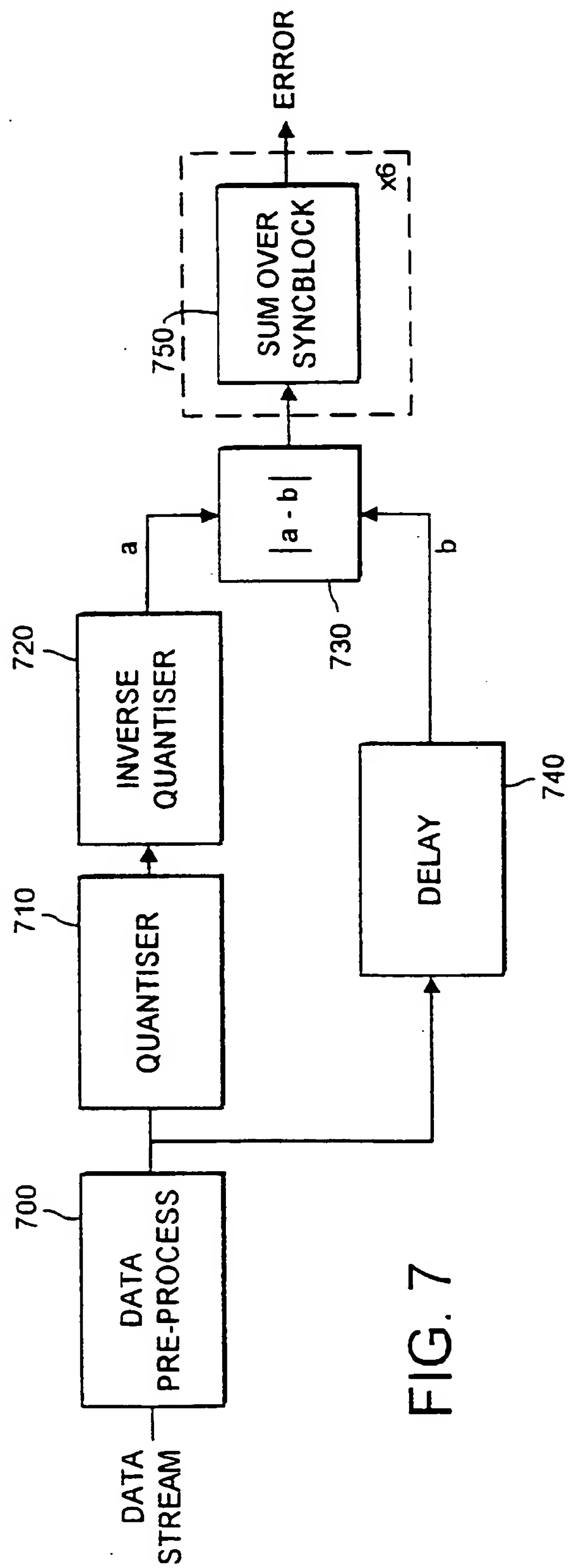
DATA
STREAM
DATA
PRE-PROCESS
700
QUANTISER
710
INVERSE
QUANTISER
720
a
|a - b|
730
b
DELAY
740
SUM OVER
SYNCBLOCK
750
x6
ERROR

FIG. 7

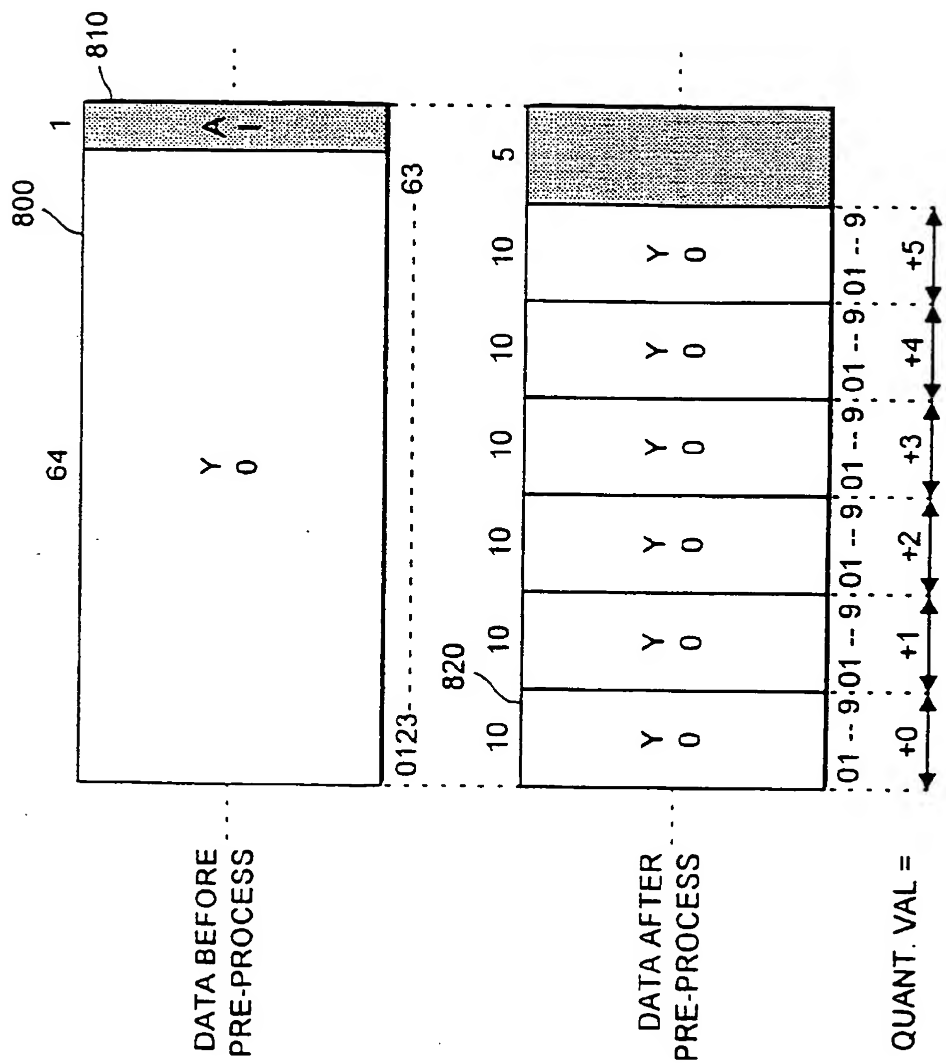
DATA BEFORE PRE-PROCESS
DATA AFTER PRE-PROCESS
QUANT. VAL =
800
810
820
64
1
Y 0
A I
0123
63
10
5
01 -- 9 01 -- 9
+0
+1
+2
+3
+4
+5

FIG. 8

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(57) Data compression apparatus in which input data is compressed according to a target output data quantity using a stage of data quantisation, the apparatus comprises: one or more trial quantisers for selecting a degree of quantisation so that the target output data quantity is not exceeded; a data selector for selecting a subset of the current data to be quantised; a data store for storing the subset of data; a backsearch quantiser and dequantiser for sequentially quantising and dequantising the subset of data at a plurality of degrees of quantisation including the degree of quantisation selected by the trial quantiser(s) and one or more harsher degrees of quantisation; a comparator for comparing data quantised and dequantised by the backsearch quantiser with the stored subset of data, to detect errors introduced by the quantisation and dequantisation by the backsearch quantiser; and a quantisation selector for selecting a final degree of quantisation for use in compression of the current data, the final degree of quantisation being that degree detected by the comparator to introduce the fewest errors during quantisation and dequantisation of the subset of data by the backsearch quantiser.

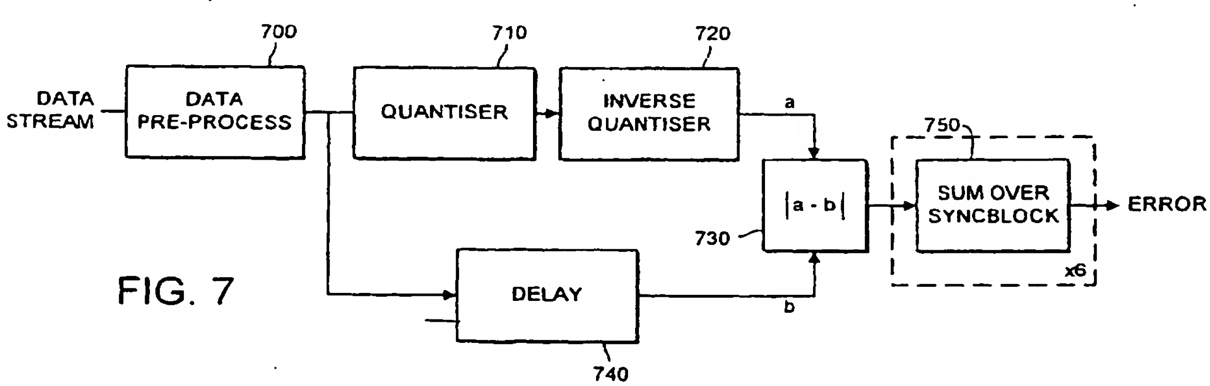

FIG. 7

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 30 1586

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 469 648 A (AMPEX) 5 February 1992 (1992-02-05) * abstract * * page 4, line 31 - page 5, line 27 * * figure 1 * ---	1-9	H04N7/30
A	EP 0 509 576 A (AMPEX) 21 October 1992 (1992-10-21) * abstract * * page 11, line 43 - page 13, line 5 * * figures 2,3 * -----	1-9	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31 October 2000	Barel-Faucheux, C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 30 1586

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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